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The Hickman catheter: A new hemodialysis access device for infants and small children

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Hemodialysis (HD) is now integral to the management of many children with renal failure [1–5]. However, vascular access continues to be a major limitation in the application of HD to the small patient [2, 6].

External arteriovenous (A-V) shunts have been modified for vascular access in children as small as 4 kg [7]. Unfortunately, these shunts are technically difficult and fraught with complications including thrombosis, infection, ischemia with potential limb compromise, and accidental disconnection and hemorrhage [8, 9]. In addition, some small patients require systemic anticoagulation to maintain shunt patency. These difficulties as well as the restriction of activity required in children with external shunts led to the search for alternative approaches for vascular access including internal arteriovenous fistulae and grafts. Although the A-V technique has been extended to small children by microsurgery [10], serious technical difficulties occur because of the small vessels in children weighing less than 10 kg. Further, a 6- to 8-week waiting period is required prior to fistula use. In addition, some children find each HD treatment a terrifying experience because of the venapunctures required for A-V fistulae and grafts. Polytetrafluoroethylene (PTFE) arterio-arterial (A-A) and A-V grafts have been placed in children as small as 3.8 kg [11] and have advantages of shorter waiting periods before use and little or no need for continuous anticoagulation. PTFE grafts, however, present problems including thrombosis, infection, and pseudoaneurysm formation [12, 6]. Long-term follow-up of pediatric PTFE grafts is not yet available, but vessel loss and impairment of limb growth are concerns [13].

Previously, the need for immediate HD access in small patients was met with umbilical vessel catheters, jugular or femoral vein cutdowns, or large percutaneously placed catheters [1]. These approaches have been complicated by infection, thrombosis, bleeding and, frequently, vessel loss in small patients. Subclavian catheter access for short- and long-term dialysis in children appears to have similar inherent problems with accidental disconnection and infection [14].

As an alternative, we investigated the use of an indwelling right atrial (RA) catheter (Hickman catheter) for vascular access in small children and report our experience with 28 catheters in 26 small patients.

Methods. The Hickman catheter® (Evermed, Medina, Washington) is a modification of the Broviac catheter employed for parenteral nutrition in many patients [15, 16]. It is constructed of polymeric silicone rubber with a single end hole, an internal diameter of 1.6 mm, and a variable length. A Dacron felt cuff is used for subcutaneous fixation, and a Luer-adapted external end allows repeated access.

While the patient was under light general anesthesia, the catheter was inserted into the RA or superior vena cava (SVC) through a venotomy in the external or internal jugular vein with preservation of both proximal and distal vessel segments. The position of the catheter tip was assurred radiographically, and, by attaching a syringe to the catheter, adequate blood flow for dialysis was demonstrated. If necessary, the catheter was repositioned to achieve the desired flow. The catheter was then tunnelled subcutaneously several centimeters from the venotomy site to exit through the skin. Wounds were inspected and dressings changed every other day. The skin exit site of the catheter was covered with Opsite® (Acme United Corp., Bridgeport, Connecticut), permitting easy observation and relatively unrestricted activity and bathing. A dilute heparin solution (100 U/ml) filled the catheter between dialyses, and, twice daily, using aseptic techniques, nurses or parents irrigated it with 3 ml of the same solution; the catheter was clamped and dressed in a standard fashion between uses [17]. Outpatient care of the catheter was performed by the parents of 13 patients without difficulty. Catheter removal required cutting the skin sutures and applying steady traction on the catheter.

Dialysis treatments utilized a single needle technique with a unipuncture clamp (Gambro Inc., Barrington, Illinois), either a Mini Minor or Lundia Minor dialyzer (Gambro Inc.) and standard neonatal or pediatric blood lines [1]. With the unipuncture system, the minute volume delivered to the dialyzer [18] was adjusted to obtain BUN clearances of 3 ml/kg/min for 4 to 6 hr three times a week [1]. The percentage of recirculation was calculated using simultaneous dialyzer arterial and venous and patient peripheral venous creatinine values [19].

For comparison the medical records of 14 age- and weight-matched children treated between 1971 and 1980 with a pediatric Scribner shunt as their first or second dialysis access at the University of Minnesota, Minneapolis, Minnesota, were analyzed.

Results and Discussion. The Hickman catheter provided dialysis access for 26 small children (Table 1) at the University

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Table 1. The Hickman catheter as dialysis access

Patient no.	Sex/age *months*	Wt *kg*	Renal disease	Catheter site	Days in place	Dialysis treatments	Blood flow to dialyzer *ml/min*	Complications/response	Other catheter uses
1	F/30	6.6	CNS, RTX	RIJ-RA	41	13	40	—	CVP, ALG
2	F/16	7.4	Oxalosis, RTX	RIJ-RA	23	1	36	—	CVP, ALG
3	F/11	4.0	CNS, RTX	RIJ-SVC	49	32	24	Poor flow in SVC	CVP, H
4	M/25	5.0	DK, CRF	RIJ-RA	154	67	22 to 24	—	CVP, H, ALG
5	M/36	12.2	Familial nephritis, RTX	RIJ-RA	30	7	40 to 60	—	CVP, ALG
6	F/108	11.8	Jeune's, CRF	REJ-RA	90	32	60 to 70	Poor flow in SVC; surgically repositioned	CVP
7	F/26	11.8	HUS, CRF	LEJ-RA	173	75	55	—	CVP, ALG
8	F/5	6.9	HUS	REJ-RA	4	1	18	—	—
9	M/38	10.7	DK, RTX	RIJ-SVC	31	12	24 to 38	Catheter port cracked; removed	—
10	F/18	12.5	HUS	REJ-RA	11	5	40 to 60	—	—
11	M/62	12.0	CNS, RTX	REJ-RA	28	14	40	Local infection; sepsis-removed	—
	M/63	12.3	CNS, RTX	LEJ-RA	389[a]	146[a]	50	Local infection-treated	CVP, ALG
12	M/14	12.7	HUS	RIJ-RA	7	3	24	Catheter perforated; removed	—
13	M/34	12.4	HUS	REJ-RA	30	16	50 to 60	Poor flow in REJ; surgically repositioned	H
14	M/23	11.6	DK, RTX	REJ-RA	27	2	42	Poor flow; repositioned without surgery	ALG
15	F/45	10.3	CNS, RTX	REJ-SVC	24	11	35	Poor flow in SVC	—
				RIJ-RA	60	25	55	New catheter for better flow	CVP, ALG
16	F/11	6.5	DK, CRF	RIJ-RA	244[a]	104[a]	40	Local infection-treated	—
17	F/6	6.2	Oxalosis, RTX	RIJ-RA	45	13	36	—	CVP, ALG
18	F/7	5.7	Oxalosis	RIJ-RA	3[a]	2[a]	26	—	—
19	M/6	4.9	DK, RTX	RIJ-RA	132	9	18	—	CVP, ALG, H
20	M/72	23.8	Ureteral obstruction	REJ-RA	62	1	45	—	H
21	M/6	4.6	DK, RTX	RIJ-RA	21	10	18	—	CVP, ALG
22	F/49	9.8	DK, CRF	REJ-RA	16[a]	10[a]	32	—	—
23	M/23	12.5	DK, RTX	REJ-RA	20	1	28	—	CVP, ALG
24	M/164	17.7	DK, RTX	LEJ-RA	59	5 (23[b])	44	Insufficient flow for efficient dialysis	CVP, ALG
25	M/96	14.25	DK, RTX	REJ-SVC	62	6 (23[b])	45	Insufficient flow for efficient dialysis	CVP, ALG
26	M/84	13.5	FGS, CRF	LIJ-RA	13	5	50	Insufficient flow for efficient dialysis	

Abbreviations: renal disease: CNS, congenital nephrotic syndrome; DK, dysplastic kidneys; CRF, chronic renal failure; RTX, renal transplantation; HUS, hemolytic uremic syndrome; FGS, focal glomerulosclerosis; site: RIJ, right internal jugular; LEJ, left external jugular; RA, right atrium; SVC, superior vena cava; other: CVP, central venous pressure; ALG, anti-lymphocyte globulin; H, hyperalimentation.

[a] The catheter was still in use as of October 1, 1982.

[b] The catheter was used for additional HD treatments as the venous return line.

of Minnesota from October 1980 to October 1982. With unipuncture technique, BUN and creatinine clearances of 3 to 4 ml/kg/min were consistently achieved with dialyzer blood flow rates up to 50 to 60 ml/min. At catheter flow rates greater than 140 ml/min excessive resistance to blood return or inadequate flow regularly occurred. Because of the small dead space (less than 1 ml), the percentage of recirculation in our single needle system was acceptable (12 to 20%), and blood flow rates were increased proportionately to compensate for recirculation and to obtain desired clearance rates.

The usual length of the dialysis treatment was 4 to 6 hr, and postdialysis BUN measurements were invariably less than 50% of pretreatment values. During dialysis the transmembrane pressure ranged from 50 to 300 torr in most patients. Excessive obligatory ultrafiltration was not a problem. In our single attempt to dialyze with the smaller diameter Broviac catheter blood flow was inadequate, and subsequently, only Hickman catheters were used. Based on a BUN clearance of 3 ml/kg/min [1], the Hickman catheter did not provide sufficient blood flow for regular dialysis in children over 13 kg (patients numbered 24 to 26, Table 1).

The distal end of the catheter was routinely placed in the RA after blood flow problems occurred when catheter tips were located in the SVC (Patients 3, 6, and 15, Table 1). One patient experienced reduced blood flow with the catheter tip in the low RA; blood flow was improved after the catheter was withdrawn under local anesthesia to the mid-RA. Occasionally, blood flow from a Hickman catheter changed during dialysis without obvious movement of the catheter tip on x-ray. Usually repositioning the child to the left lateral decubitus or prone position improved the blood flow, suggesting that the catheter tip was against an endothelial surface. No catheters were advanced further into a vessel after placement because of infectious risks. One catheter, in patient 13, slipped into the external jugular vein after 2 weeks of use and required surgical replacement over a guide wire.

The catheters served other functions, including postoperative central venous pressure (CVP) measurements (15 patients), hyperalimentation (5 patients), and antilymphocyte globulin administration (14 patients).

Serious catheter complications were recognized rarely. In one patient nonelective catheter removal and antibiotic therapy, dictated by fever and a positive *Staphylococcus aureus* blood culture (patient 11), led to resolution of the infection. In this patient local erythema and bloody drainage from the catheter exit site were noted 2 days prior to the development of fever. Another patient had bloody drainage from the subcutaneous tunnel during several dialyses; the bleeding ceased with local pressure, and no infection was detected. Additionally, two children (patients 11 and 16) developed local skin infection that responded to parenteral antibiotic therapy without catheter removal. One catheter with a cracked Luer adaptor (patient 9) was removed since it was no longer required. In one patient the tubing was perforated (patient 12) and repaired without complication using a Hickman Repair Kit® (Evermed). No clotted catheters or embolic episodes were recognized. There was no clinical evidence of arrhythmia, endocardial injury, or pulmonary embolus in any patient.

We used the Hickman catheter in small children with acute renal failure or when dialysis prior to renal transplantation was anticipated. The catheter had several features desirable in a short-term hemodialysis access device. Silicone rubber is less thrombogenic than other catheter materials [20]; infection may be impeded by both the long subcutaneous tunnel and the Dacron cuff [21], and importantly, an appropriately placed catheter allows immediate dialysis access.

Additional advantages of the Hickman catheter became apparent during our experience. Surgical placement was relatively simple when compared to the expertise and time required for creation of an effective pediatric shunt. Little restriction of the child's activity was required. Chronic care, including intermittent heparin irrigation, was sufficiently simple for parents to manage. No systemic anticoagulation was required. The venotomy technique may allow vessels to be used more than once. Finally, in addition to dialysis access, CVP measurements, hyperalimentation, and drug administration were possible.

Our complications compared favorably to our past experience with pediatric Scribner shunts in a matched group of infants and small children (Table 2). The incidence of thrombosis, bleeding, local infection, surgical revision, and non-elective access removal appeared higher with the Scribner shunt. Our experience with A-V shunts in small children was similar to that reported in larger children [6]. Franzone [8] indicated that 50% of children with A-V shunts experience at least one thrombotic episode, and Idriss et al [9] noted a thrombosis and/or infection rate of 40% in their children. The experience of Kon et al [14] with subclavian catheter dialysis in 17 children demonstrated significant problems with bleeding (12%) and sepsis (29%). Our experience showed the Hickman catheter with its subcutaneous tunnel was less prone to bleeding (7%) and sepsis (4%).

Experience with internal fistulae in children under 15 kg is limited. Bourguelot, Wolfeler, and Lamy [10] reported a failure rate of 43% in 21 children under 10 kg who underwent the microsurgical creation of an A-V fistula. Robinson, Wenzl, and Williams [11] reported one episode of thrombosis and two episodes of pseudoaneurysm formation in over 200 dialysis treatments in three children between 9 and 16 kg with PTFE A-A grafts. Applebaum et al [22] reported a low complication rate for 25 A-V PTFE grafts in children; however, they weighed between 12 and 56 kg. Our results thus compared favorably with those of internal A-V grafts and fistulae in small children.

Table 2. Pediatric access devices: Use and complications

	Hickman catheter	Scribner shunt
Patients	26	14
Age range, *years*	0.5 to 13.7	1.1 to 4.6
Median age, *years*	2.1	1.8
Weight range, *kg*	4.0 to 23.8	4.7 to 13
Median weight, *kg*	10.7	10.0
Number of devices	28	16
Number of dialyses	634	377
Days of catheter life	1873	901
Average days catheter life per patient	66.9	64.4
Complication free devices	16/28	2/16
Complications:[a]		
Thrombosis	0/1873	1/30
Bleeding	1/936	1/100
Local infection	1/624	1/150
Sepsis	1/1873	1/901
Surgical revision	1/624	1/150
Nonelective removal	1/468	1/300
Systemic anticoagulation	0/1873	1/60

[a] Values are expressed as event/days at risk.

Although desirable for long-term hemodialysis, A-V grafts in tiny children present a formidable-surgical challenge and require significant maturation prior to use. Therefore, in acute renal failure or for brief periods of dialysis in preparation for transplantation, the Hickman catheter may be the preferred form of access. The Hickman catheter may also be used for temporary access while awaiting fistula maturation in children likely to require long-term HD. Moreover, the safety of the Hickman catheter in uremic children compares favorably with the experience in adult bone marrow transplant patients and in children and adults on prolonged parenteral nutrition [20, 15].

The Hickman catheter afforded safe and reliable vascular access in infants and children up to 13 kg in weight. Adequate blood flow always required placement of the catheter tip in the RA or at the RA-SVC junction. We are now using this method preferentially to meet short-term dialysis needs in small patients with acute renal failure, before and after renal transplantation, and while awaiting maturation of A-V fistulae or grafts in larger children. A trial with a larger bore catheter in children weighing more than 12 kg is now underway in our institution to determine whether or not this technique may be useful for larger children in similar clinical settings.

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